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Smart pebbles go hiking: in-situ measurements of grain scale dynamics using inertial sensors in mountain streams.

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Single coarse grain scale measurements relate directly to the study of sediment transport in mountainous streams, primarily because these streams are characterised by a mixed and variable riverbed bed topography (ranging from "bare bedrock" to "fully alluvial"). Quantifying the force regime that controls the transport of a single pebble in situ has been proven historically difficult. Most of the measurement techniques are measuring indirect cross-averaged or point (non-inertial to the grain) transport metrics and using those to describe or predict grain motion (probabilistically or deterministically). The introduction of inertial Micro Mechanical and Electrical Sensors (MEMS) sensors (sensor-assemblies that comprise of micro-accelerometers, gyroscopes and compasses) to this problem, triggered the idea of a "smart-pebble": a mobile stone-like assembly that can measure directly the forces (and consequently metrics such as grain velocities, positions, kinetic energies etc.) of sediment transport exactly as experienced by single grains (from their inertial frame). Today, almost ten years after this idea was introduced in the literature, we know that there are accuracy limitations on the use of the MEMS suitable for monitoring fluvial transport (mainly relevant to unrestricted calculations of grain position, tracking) but we also know that there is a potential to calculate directly single pebble dynamics for short time scales and after consistent calibration and analysis. In this presentation, in-situ measurements from two purpose specific smart pebbles will be presented, deployed in three different mountain river stretches. The first dataset (river Calder, Scotland) is the collection of pre-entrainment pebble vibrations (20-minute periods), in low flow conditions. The second dataset is the measurement of seven complete single pebble transport events (entrainment- translation-deposition), derived from an alpine river (Erlenbach, Austria) during the snowmelt season (April 2018). Finally, the third dataset relates single pebble transport events with coherent ADCP measurements, both collected in the upstream region of river Dee (Scotland) during moderate/high flooding conditions. The three datasets are connected using an "exceedance over threshold" analysis, which is formalised after the re-working of an, experimentally tested, fundamental Newton-Euler model.